Project Summary

Project Title:

SENSITIVITY OF PACIFIC ISLAND TROPICAL MONTANE CLOUD FORESTS TO CLIMATE CHANGE

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Duration of project: 5 Years
Annual funding requested from GC program: $ 212,000
Total funding requested from GC program: $ 1,060,000

Biogeographic Feature/ Region(s):
2. Coastal areas, Islands, Coral Reefs (primary)
1. Montane Regions
7. Forests

Thematic Area(s)
3. Terr and aquatic plant & animals & habitats
5. Invasive, non-native species
6. Climate variability, 9. Modeling
8. Watershed response, hydrology

Key words: Tropical Montane, Pacific Islands, Cloud Forests, Hydrology

Abstract:
The linkages between cloudwater hydrology and high species endemism in a narrow altitudinal zone make tropical montane cloud forests (TMCF) potentially among the most vulnerable to loss of biodiversity through climate change. This project will continue to collect and summarize long-term data on the microclimate of TMCFs of the Pacific Islands, with an emphasis on the hydrology of cloud forests of the Hawaiian Islands. An explicit cloudwater interception model will be developed to estimate how the spatial distribution of cloudwater interception will change in response to changes in the lifting condensation level and tradewind inversion that determine the limits of montane cloud forests in the Pacific Islands. Paleoecological methods will be expanded to employ aquatic insects to develop multiple proxies for past climates and to better understand the changes in the size of TMCFs and ecosystem response to climate change. Data on native aquatic indicator species of hydrologic change collected during the first 5 years of this continuing project will be coupled with data on invasive mosquitoes from a concurrent NSF Biocomplexity study of avian disease to model feedbacks of potential climate change on aquatic communities along temperature gradients, including how changes in hydrology associated with the loss of cloud forest biodiversity may influence the spread of disease in the Pacific. This information will be used to evaluate current resource management practices and as a guide for restoration of TMCFs and their transitional zones in DOI National Parks and Wildlife Refuges of the Pacific. The proposed work will help address more than ten specific research needs identified in the ecosystems element of the July 2003 Strategic Plan for Climate Change Science Program as well as contributing to research objectives identified in 5 out of 6 of the goals of the 5-year USGS-BRD Global Science Change Program.

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JUSTIFICATION & OBJECTIVES

Need

On August 29th, Governor Linda Lingle declared another year of statewide drought for Hawaii. It is the fourth consecutive year that the state as a whole has been under such conditions (and much longer in some locations). Currently we are experiencing a mild to moderate El Niño Southern Oscillation (ENSO) event. Based on past events, we can expect lower than normal rainfall during the winter months. Our growing data base of climatological observations provide a basis for evaluating the effects of ENSO-related climatic variability on the biological resources of Haleakala and Hawaii Volcanoes National Park. We believe El Niño periods may provide an analogue for a future greenhouse climate in Hawa`i. Of particular interest in this regard is the sensitivity of the trade-wind inversion to ENSO fluctuations. We have evidence that El Niño events are associated with a lower, stronger, more persistent trade-wind inversion (Tran, 1995). This condition lowers the upper limit of the fog and high rainfall zone on Haleakala's slopes. Recent evidence obtained elsewhere (Pounds et al., 1999) suggests that warming may also raise the cloud base, thus further narrowing the fog/high-rainfall zone.

The most obvious climatic change to be expected during this century is increasing temperature associated with the build up of radiatively-active gases in the atmosphere. It is often assumed that temperature trends in tropical maritime locations will be less pronounced. Additionally, findings by researchers such as Spencer and Christy (1992) that tropospheric mean temperature trends have not matched surface warming, suggest that high elevations may experience more moderate warming than lower elevations. However, the observed temperature trends in Hawai'i indicate rapid warming at surface ***AND*** high elevation stations during the 20th century. The time series of annual temperature is shown in Figure 1a for Honolulu, Hilo, and Haleakala Ranger Station (2100 m). Trends are computed using linear regression. The extreme warming at Honolulu is undoubtedly due in part to urbanization. However, at Hilo, with much less urban development, and less exposure to the effects of urbanization and other land cover changes because of it's windward coastal location, the trend is also pronounced. The temperature record at Haleakala Range Station is unlikely to have been affected by any local land cover changes, and is therefore indicative of atmospheric change affecting Hawai'i's middle and upper elevation slopes. In Figure 1b, five-year moving averages of Haleakala and global temperature anomalies are shown. The general pattern for the two time series is similar, with little or no apparent trend from the mid-1940s through 1970, followed by pronounced warming through the end of the century. However, note that the magnitude of the warming at Haleakala during the last 30 years of the 20th century (3°C per 100 years) was approximately double that of the global mean.

Tropical montane cloud forests (TMFC's) are zones of great hydrological and ecological value. "An urgent need for readily available, reliable information on a site by site basis has been identified, in order to provide the background for raising public and political awareness of the importance of TMCFs, and promoting their conservation and sustainable use." (Aldrich 1998). Long-term conservation of TMCFs requires comprehensive scientific knowledge of hydrological and ecological function, however, "compared with almost all other major forest ecosystems, tropical montane cloud forests have been subject to little research" (Bruijnzeel and Hamilton, 2000).

Within the cloud zone, vegetation strips droplets from the passing air, thereby, making fog interception a source of precipitation adding to rainfall (Bruijnzeel, 2000). Fog interception and transpiration suppression during frequent and prolonged wet-canopy periods, generate high watershed yields, supporting water resource needs of downstream regions.

Loss of forest cover in montane fog zones greatly reduces fog interception, potentially altering the regional hydrology. TMCF are threatened in the Pacific by alien species invasion and globally by expansion of agriculture, fuel wood cutting, and timber harvesting (Lawton et al. 2001). Recently, other threats, linked to global climate change, have been revealed. Fog frequency in TMCFs at Monteverde, Costa Rica, declined dramatically in response to a step-like warming of tropical oceans in 1976 (Pounds et al. 1999) leading to speculation that global warming will negatively impact hydrological and ecological function in tropical maritime cloud forests (Foster 2001). This finding was supported by global climate model simulations showing upward shifts of 183 to 341 m in relative humidity surfaces at four TMCF sites for a 2 x CO_2 climate (Still et al. 1999).

Studies of the biogeochemistry of Hawaiian ecosystems have shown that, in cloud forests, the most significant input of many elements is via fog interception (Heath and Huebert 1999; Heath 2001). Fog interception estimates in Hawai`i vary widely (Juvik and Nullet 1993), but recent isotope analysis of stream and groundwater (Scholl et al. 2002a,b) and canopy water balance observations (Heath 2001; Giambelluca and Niemand, in preparation) suggest it may be responsible for a larger proportion of the hydrological input in Hawai'i than previously thought.

With extreme climatic gradients, windward slopes of high mountains in Hawai`i generate surface flows and provide groundwater recharge to meet the State's water resource demands (Giambelluca 1983, 1986). Groundwater resources, crucial to Hawai'i’s economic development and to the sustainability of the State’s growing residential population, are already stressed. Mandatory conservation measures are commonplace in many areas to protect threatened groundwater sources, especially during ENSO-related dry periods (Giambelluca et al. 1991). The State’s most productive aquifer, Pearl Harbor Aquifer on O'ahu, is designated for special regulation by the State Water Commission (SWC), placing a virtual moratorium on new groundwater development (Giambelluca 1986). Hearings are currently underway for designating Iao Aquifer on Maui.

Ecologically, tropical montane cloud forests (TMCFs) often form "islands" of biodiversity, supporting a high proportion of endemic species (Bruijnzeel and Hamilton, 2000). Effects of elevation and aspect give rise to extreme heterogeneity in environmental conditions providing habitats for species not found elsewhere.

Kaneshiro (1989) argued that Hawai’i’s native biota provides the world’s best laboratory for evolutionary studies and is the state’s single most important natural resource. While human impacts have become pervasive in the lowland landscapes of Hawai’i, the high-elevation ecosystems remain relatively intact (Medeiros et al. 1995). Native plant and animal species in Hawaiian TMCF are marked by extremely high rates of endemism (ca. 95% for flowering plants, ca. 50% for ferns, and ca. 65% for invertebrates). The native birds of Hawai'i are vulnerable to human impacts. For example, only 22 of the estimated 52 endemic Hawaiian honeycreeper species survive, 14 of which are classified as endangered (Medeiros and Loope 1994). For many of these species, Hawaiian cloud forests are their last refuge.

Concern about the ecological, hydrologic, climatic, and biogeochemical effects of destruction of tropical rain forest has raised interest in tropical forest hydrology, especially in understanding how rainfall is partitioned among canopy, understory, litter, and soil, and quantifying rates of evapotranspiration (ET) (Bruijnzeel 2001, Giambelluca, 2002, Hölscher et al. 1998, Marin et al. 2000).

Hydrologic changes with the potential to impact TMCFs appear to be already underway. The ten driest years in the past century in Hawaii all coincided with El Niño winters and we are observing a high frequency of such events currently (Figure 1c). Significant reduction in stream base flow is also suggested from long-term data, such as those from Maui (currently under study in collaboration with USGS-WRD) and Molokai (Figure 1d). In the last five years of USGS-funded work we have focused on high elevations and the tradewind inversion. However, additional data is urgently needed to understand the hydrology of cloud forests, including the spatial patterns of cloud water interception and, specifically, the height of the lifting condensation level that determines the lower elevation limit of fog interception. We also need paleoecological data that will better elucidate variation in the extent of TMCFs and their sensitivity to climate change on a larger temporal scale. Lastly, outbreaks of dengue fever in 2001 on Maui, during the drought, and American Samoa (to name two of several locations) indicate that there may be important feedbacks between upper elevation cloud forest hydrology, the composition of aquatic communities downstream and population dynamics of mosquitoes that serve as vectors of both human and wildlife disease. We can use existing data collected from past USGS Climate Change Program and NSF Biocomplexity support to model system feedbacks and population outbreaks of disease vectors. This will add an important new dimension to our existing focus on aquatic indicator communities.

Scientists in PIERC and their collaborators in this project will be conducting research to help address questions identified in the ecosystems element of the **US Climate Change Science Program Strategic Plan** (July, 2003), including one of the two overarching questions identified in the 10-year plan: How do natural and human-induced changes in the environment affect the structure and functioning of ecosystems at a range of spatial and temporal scales, including those processes that can in turn influence regional and global climate? Our focus will be on the hydrology of cloud forests with a paleoecological component to bring in larger temporal scales and an expanded geographic focus including sites above (Hawaii) and below (American Samoa) the equator in the tropical Pacific. The research will bring together the capabilities of three existing field stations in the Hawaiian Islands that maintain some of the longest temperature records and one of the most sophisticated microclimate networks (operating since 1988) anywhere in the Pacific Islands.

Specific Objectives

1. Continue measurements of interannual microclimatic variability for TMCFs at Haleakala and Hawaii Volcanoes National Parks; expand the network to include a TMCF in the National Park of American Samoa (NPSA) as a representative TMCF for the southern tropical Pacific; and develop a model of cloud water interception based on surface wind velocity, liquid water content of surface air, and canopy characteristics.
2. Sample paleoecological indices of the presence of cloud forest vegetation, including chironomids, to determine past changes in climate and the height and extent of cloud forest in Hawaiʻi and American Samoa.

3. Examine feedbacks between TMCF hydrology, climate change and aquatic communities to better understand the patterns of population outbreaks mosquitoes that serve as disease vectors.
4. Use information gained in the first three objectives to provide DOI land managers with guidance on restoration projects focused on TMCF sites with a long history of disturbance, including Hakalau Forest National Wildlife Refuge and the new 2003 116,000 acre Kahuku tract addition to Hawaii Volcanoes National Park

Meeting the Goals of the USGS Climate Change Program

Our first objective will address the first and third goals of the USGS Climate Change Program (USGS-CCP) by evaluating the sensitivity of TMCFs using hydrologically-defined indices of ecological response. As pointed out above, TMCFs represent geographic areas that are considered at high risk of loss or injury due to climate change.

Meeting our first two objectives will contribute to the need to develop projects that assess the impacts of interannual variability on the system dynamics of TMCFs at a range of spatial scales, ranging from microclimates of a single mountain slope to regional trends identified in a cross-site comparison between the northern (Hawaiian Islands) and the southern, equatorial (American Samoa) tropical Pacific. The continuation of our long-term climate monitoring in Hawaii National Parks (our objective 1) will allow us to better understand the impacts of interannual variability on TMCFs (USGS objective 3.3)

Our second objective will also address the first goal of the USGS-CCP by helping to determine trajectories and thresholds of climatically-driven ecological change in TMCFs and to determine where state changes may occur requiring new management alternatives, such as restoration of previously degraded communities. As pointed out above, data from the Hawaiian Islands suggest that rates of global warming are matching, if not exceeding global mean rates of change. This fact coupled with the impact of invasive species in TMCFs as prevalent stressors supports the need for USGS attention.

An examination of the feedbacks between climate change, TMCF hydrology and aquatic communities (our objective 3) will explicitly examine the role of trophic interactions on invasive alien arthropods and the relationship between changes in base flow and population outbreaks of alien organisms. The work includes three objectives (changes in stream flow, trophic interactions, and invasive species response) of USGS-CCP program goal 2, determining causal mechanisms underlying ecosystem responses to global change.

Our forth research objective will explicitly address USGS-CCP objectives 4.3 for developing techniques to make TMCFs less vulnerable to climate change, making use of data gathered under our first three objectives to set realistic targets for restoration. Our work will also meet USGS-CCP objective 6.2 by implementing adaptive management approaches for the restoration of TMCFs.

The proposed study sites are shown in Figure 2 and listed in Table 1. Expansion of our network into the western Pacific is motivated by the desire to better understand regional threats to TMCFs in the Pacific Basin. Meehl (1998) has shown that average climate change in the Pacific region from increased carbon dioxide (CO2) in a global coupled ocean-atmosphere general circulation model is characterized by greater warming of surface waters in the eastern tropical Pacific than in the west, leading to increases in precipitation in the south-central equatorial Pacific accompanied by decreases in the northern tropical Pacific. Our understanding of climate of South Pacific islands is largely based upon sea level measurements. There are no representative data for TMCFs. Our objective is to establish a climate station in the cloud forest on Ta`u (960m, figure 2a and 2b) within the boundaries of the National Park of American Samoa (NPSA) situated about 14° S latitude and exposed to southeasterly tradewinds (Whistler, 1995). The rational to situate a climate station at NPSA parallels efforts by the Climate Monitoring and Diagnostics Laboratory (CMDL) of the National Oceanic and Atmospheric Administration (NOAA). NOAA established a monitoring project to observe the sea-level climate and atmospheric constituents of the tropical Southern Hemisphere at Cape Matatula, American Samoa, in 1973**.** The CMDL maintains a network of climate stations that includes Mauna Loa Observatory in Hawaii Island. Data from a montane site at NPSA would offer valuable insight into the impact of regional climate change on TMCFs in the Pacific, as well as providing important high-elevation data for the tropical Southern Hemisphere.

Table 1. Major Tropical Montane Cloud Forests in the Pacific Islands (after Hamilton, et al. from the same volume as Whistler, 1995) with proposed study sites.

Island Group	Island	Mountain	Elevation	USDI Study Sites
Papau	New Guinea	Jaya Peak	5040	
Papau New Guinea	New Guinea	Mt. Wilhelm	4509	
Hawaiian Islands	Hawaii	Mauna Kea	4205	Hakalau NWR
Hawaiian Islands	Hawaii	Mauna Loa	4169	Hawaii Volcanoes NP
Hawaiian Islands	Maui	Haleakala	3055	Haleakala NP
Solomon Islands	Guadalcanal	Mt. Popomanaseu	2330	
French Polynesia	Tahiti	Mt. Orohena	2241	
Vanuatu	Espiritu Santo	Mt. Tabwemasana	1879	
Samoa	Savaii	Mt. Silisili	1858	
New Caledonia	New Caledonia	Mt. Panie	1628	
Fiji	Viti Levu	Tomanivi	1323	
Tonga	Kao	Kao	1046	
American Samoa	Tau	Tau	960	NP American Samoa
Federated States of Micronesia	Pohnpei	Totolom	791	
Cook Islands	Rarotonga	Te Manga	653	
American Samoa	Olosega	Olosega	640	

Background This is a proposal for continuation of a previously funded project under the USGS-CCP in 1999 entitled- “Developing a listening post in the tropical Pacific: Sensitivity of Hawaiian high-elevation and aquatic ecosystems to global change”. Here is a summary of the project:

> Knowledge of tropical climate variability and the sensitivity of tropical climate to global climatic change is a crucial element of current efforts to understand past climates, predict future climates, and anticipate ecological responses to global warming. High-elevation ecosystems of the Hawaiian Islands appear to be highly vulnerable to relatively small shifts in global weather patterns and provide potentially valuable "listening posts" in the tropical Pacific Ocean to assess climatic stability in the tropics from the present into the near future. The position of the North Pacific subtropical anticyclone and the altitude of the trade wind inversion (TWI) are fundamental drivers of local rainfall, cloud cover, and humidity. There are currently two competing models of effects of global climate change on these high-elevation ecosystems: one, involving more frequent and intense El Niño events (with accompanying drought) and the other involving a simple raising of vegetation zones without marked increase in drought. We

addressed the most likely biological effects of the drought scenario, comparing microclimate, hydrology and ecological effects of extreme El Niño conditions with "normal" conditions. We also simultaneously pursued the alternate scenario of rising zones through expanding and refining pollen analyses of vegetation changes in high-elevation bogs during past warm periods in the earth's history.

Climate monitoring at Haleakala and Hawaii Volcanoes National Parks

On Maui, we have been operating HaleNet, a network of micrometeorological observing stations, since 1988 (with support from the USGS Global Change Program beginning in 1999). HaleNet is comprised of 11 sites (9 active) along the leeward and windward slopes of Haleakala volcano, Maui Island, Hawai`i (see http://webdata.soc.hawaii.edu/climate/HaleNet/Index.htm for a description of the network or to view statistics; see also Figure 2d below). Each station measures solar and net radiation, infrared surface temperature, soil temperature, soil heat conduction, air temperature and relative humidity, wind speed and direction, soil moisture, and rainfall. Six stations in the network are within Haleakala National Park. For many years this network has supported a variety of research and operational activities within the park, including the numerous species invasion issues of concern to BRD scientists and park resource managers (Loope and Giambelluca 1998). Two sites (one active) were equipped with throughfall and stemflow collectors, fog collectors (for quantity and to obtain samples for stable isotope analysis), and a visibility sensor to detect the presence of fog.

Continued monitoring at the HaleNet sites will provide continuity with the current project and support numerous activities in the proposed study. Data collected by this network are invaluable for many reasons, including establishing the baseline for assessing climate change, providing reference climate information for interpreting paleoecological data, giving near-real-time information regarding climatic variability, such as ENSO-related shifts in vertical climate zonation, and allowing assessment of the spatial patterns of hydrological fluxes below, within, and above the trade wind inversion layer along Hawaiian mountain slopes.

During 2002, with the cooperation of Hawaii Volcanoes National Park (HAVO) and support from the University of Hawai'i, we took the important step of installing a 25-m (80-ft) tower at a prime native forest site near Thurston Lava Tube in HAVO. Using funding from the University of Hawaii, we previously purchased equipment to support a full state-of-the-art energy and mass flux observation station at the site. This will be the first station in Hawaii to feature highly sophisticated eddy covariance sensors for accurate measurement of energy and water vapor flux, sapflow-based transpiration observations, complete under-canopy rainfall and stem flow measurements for estimating canopy rainfall interception, and continuous monitoring of soil moisture. This elaborate system will enable the first detailed observation of water partitioning in a Hawaii forest site. The site has added significance because it is within the cloud zone. In Hawaii, no reliable quantification on fog drip has yet been completed, largely due to the lack of concurrent evapotranspiration measurements. Additional meteriological stations are being installed on Hawaii Island centered around HAVO with support from the USGS Global Change Program and a concurrent NSF Biocomplexity Project on avian disease (see figure 2c). These HAVONet stations, positioned along elevational gradients, will help quantify the limits of TMCFs on Hawaii Island.

Paleoecology of Tropical Montane Cloud Forests

Knowledge of the ecohydrology of Hawai`i's montane forest areas is important for water resource planning and ecosystem protection, and must be based on improved understanding of the mutual influences of hydrological and ecological processes. This work was also initiated with support of the USGS Climate Change Program in 1999. The vegetation histories we are developing along a climate gradient through treeline and the trade wind inversion record the response of high elevation vegetation to climatic change over thousands of years, with temporal resolution of several decades. Our initial results indicate that the vegetation responds primarily to changing moisture, with a secondary response to temperature. We propose to expand our investigation of ecosystem response to climate change to include insects, which may be more sensitive to changing temperature than precipitation. We will reconstruct changes in the species composition of chironomid midges, using mandibles preserved in sediment. Subfossil Chironomid assemblages are widely used to reconstruct the history of climate (e.g. Korhola et al. 2002). In addition to climate reconstruction, subfossil chironomid assemblages have been used to reconstruct environmental changes within the ecosystems they inhabit (e.g. Merilainen et al. 2000).

Chironomid analysis has not yet been widely used in tropical ecosystems, but an Australian study has demonstrated the effectiveness of chironomids for paleoclimatic interpretation in a tropical volcanic maar lake (Dimitriadis and Cranston 2001). We will develop a local calibration data set, following the strategies tested by these earlier research projects. Surface sediment samples already collected will be analyzed for Chironomid remains, and additional samples will be added to the library, extending our sampling range to lower elevation and higher rainfall areas as well as to our new study areas on Hawaii Island and American Samoa.

We have observed chironomid head capsules in sediment analyzed for vegetation history, so we know a sedimentary record is available. We will initially analyze specimens of chironomids collected as part of our previously funded project to evaluate aquatic communities of Megalagrion damselflies and their dipteran prey as indicators of hydrologic change. Taxonomic keys based upon adult and larval morphology will be developed. The Hawaiian chironomid lineages contain enough species to predict the technique will be successful in our study. In addition we will attempt to develop sedimentary records of Megalagrion damselflies to parallel studies of contemporary distributions described previously. By reconstructing the histories of both of these insect groups along elevational gradients, we will add long-term perspective to our current studies of the indicators of global change in Hawaiian montane ecosystems. Our goal is not to use the insects themselves to reconstruct climate history, but rather to use similar methods to assess the climatic tolerance of chironomids and Megalagrion in modern ecosystems and compare the rates of response of vegetation and insects to past climatic change, reconstructed with independent means. We believe that these data coupled with previous pollen data will enable us to better understand the past boundaries of TMCFs and their interaction with climate change.

Aquatic Indicator Species of Hydrologic Change

The purpose of this element of the research has been to relate temporal and spatial patterns of global climate-driven changes in forest hydrology to likely biotic responses, ranging from environmental stress responses of individual aquatic organisms to changes in species composition following the reassortment of ecologically stressed communities. The goal is to identify sensitive and reliable indicators for current and future climate change and provide baseline data at micro- and meso- scales for hydrologic systems in national parks of Hawaii to assist in the development of model predictions of regional climate change. This work contributes to one of the four key global change objectives in the FY99 USGS-CCP: quantifying dynamics and responses of terrestrial and aquatic ecosystems to climate change. The project focuses on using aquatic invertebrate biodiversity as a tool to detect biological responses to climate change. The project is providing baseline data to aid in the development of management options for adapting to global change in Hawaii and the Pacific.

We investigated the feasibility of using populations of Hawaiian damselflies (Odonata: genus Megalagrion) as indicators of ecosystem health and stability in relation to droughts associated with El Niño events in Hawaii. Drainages typically have up to five different species of Megalagrion each occupying a different aquatic habitat, ranging from riffles in perennial streams to pools, seeps, phytotelmata of epiphytes and cloud forest soil litter. The project formed the third major element of previous work supported by the USGS-CCP. Surveys were carried out in West Maui and along three major drainages of the Island of Hawaii. On Hawaii, we have focused attention on the Pahala Watershed in the Kau District adjacent to Hawaii Volcanoes National Park (HAVO, Figure 2c). The system extends from approximately 10 km of coastal pools, southwest of Hawaii Volcanoes National Park, up to Namanuaha'alou Swamp at 2000 m elevation below the Southwest Rift Zone of Mauna Loa Volcano. This region is recognized for its high potential for conservation use and, in 2003, the upper boundary of this wetland, the 116,000 acre Kahuku Tract, was purchased by The Nature Conservancy and the National Park Service, the tract will ultimately increase the size of HAVO by more than 50%.

Megalagrion damselflies and their prey base, aquatic diptera (flies), were surveyed along seasonally fluctuating temperature and moisture gradients in the ephemeral streambeds of the watershed from the coast up to 5,500' elevation. An overall reduction in Megalagrion and other odonates (dragonflies and damselflies) was noted during the cooler winter months. However, there were interactions between drainages and seasonal population abundance of *Megalagrion* damselfly species suggesting that montane and coastal communities respond differently to seasonal changes in temperature (Orr & Foote, 2003). Megalagrion were absent from the mid-elevation ephemeral streambeds and we interpreted this as a consequence of the approximately 7-year drought that this watershed has experienced.. We also noted two species of mosquitoes along the gradient, including the Southern House Mosquito (*Culex quinquefasciatus*), an important vector of avian diseases in Hawaii. Peak abundances of mosquitoes occurred around temporary pools in the lower and mid-elevations sites. This work was undertaken by Ms. Krista Orr, who is completing her Master's thesis on the project at the University of California at Davis this fall.

In order to better understand the relationship between drought and population abundance of Megalagrion damselflies, we also carried out a mesocosm experiment where we simulated the effects of drought for the pool-breeding damselfly, *Megalagrion calliphya*. Replicate sets of pools were set-up and naturally colonized by *M. calliphya* adults. We then experimentally reduced pool sizes to simulate the effects of moisture deficits and observed the response among both adult and naiad (larval) populations of the damselfly. We found that total adult population size decreased initially following simulated drought, but then rebounded as male territory size decreased to accommodate a higher male densities around the breeding pools. The density of naiads also increased, but naiads were smaller in total body size (Cooper & Foote, 2003). In the process of measuring naiad densities, we removed naiads from the pools and noted that *Culex* mosquitoes soon colonized pools where the larval damselflies had been removed. This is not surprising given that Megalagrion, like many other damselfly species, readily prey on larval diptera, such as mosquitoes, and we have reared *M. calliphya* in the lab on a diet of *C. quinquefasciatus* alone. This mesocosm work was carried out by Idelle Cooper as part of her current graduate studies at Indiana University.

To facilitate the exchange of information regarding damselflies as indicators of hydrologic change in Hawaii, Foote organized a symposium last February on conservation biology of

Megalagrion damselflies at the Pacific Entomology Conference in Honolulu. The symposium was timed to coincide with the 10-year anniversary of the first major paper published on the conservation status of the genus, by Dan Polhemus of the Smithsonian Institution. Of nine papers presented at the symposium, three were based upon work supported under the USGS-CCP. These papers will be published as a collected volume in the journal Pacific Science.

In 2001, dengue fever outbreaks occurred across the Pacific and spread to the island of Maui. The source of the outbreak in Maui was thought to be from residents returning from either Tahiti or American Samoa where dengue is endemic and current cases of the disease were also being reported. Bringing together our observations on mosquitoes from our Megalagrion surveys, we have begun discussions with our PIERC colleague, Dennis LaPointe, about the possible relationships between drought, the presence or absence of Megalagrion and mosquito population abundance at our Kau study sites. Dr. LaPointe is currently funded under an NSF Biocomplexity Project to study avian disease in communities of native Hawaiian honeycreepers. He and scientists from the National Wildlife Health Center (including Dr. Jorge Ahumada) have recently completed a study modeling the dynamics of *Culex quinquefasciatus* in an adjacent watershed in Puna Hawaii. LaPointe and Ahumada believe that the system we have described in Kau is fundamentally different from the one they are currently studying in Puna. We have developed the following working hypothesis on how drought cycles and hydrologic changes in Tropical Montane Cloud Forests may influence predator-prey interactions between *Megalagrion* and *Culex*:

The Kau forest is similar to that in Puna but differs in the presence of well-developed drainages. These intermittent streams are characteristically exposed and pitted rockbeds. Rock holes within these drainages often support mosquito larvae. The influence of climate on this habitat is considerably different from that of the small treefern cavities used by Culex larvae in Puna. Greater exposure to solar radiation in rock holes will affect water temperature resulting in profound differences in the development of larval mosquitoes. Increased solar radiation will increase evaporation rate ultimately affecting the availability of larval habitat and larval mortality as smaller rock holes dry up. Precipitation will also have a major impact on mosquito abundance. During the drier months of 2000, mosquito larvae were only found in deep rock holes in intermittent streams (LaPointe unpublished data) serving as an important refuge in times of extended drought. Here, we believe Megalagrion may be an important control on mosquito numbers. However, heavy rains and resulting spates appear to cause catastrophic mortality of both mosquitoes and damselflies in the pools. The lack of Megalagrion in the mid-elevation pools containing mosquitoes may reflect more rapid colonizing ability by mosquitoes.

It has been suggested that severe droughts generally eliminates mosquito predators (e.g. Chase, 2003; see also comment by Kaiser, 2003). We can test this hypothesis in Kau. An essential component of this proposal is the integration of the ecological processes of the system (demography of damselflies and mosquitoes and the functional interaction between them) with the relevant climate parameters that affect these processes (water temperature, ambient temperature, elevational gradients, pool dynamics, precipitation and running water patterns). We propose to achieve this integration through a modeling framework that would explicitly address the mechanisms involved at various levels:

1. Effects of water and environmental temperature on the development rate, survival and fecundity of both species.
2. Effects of intraspecific density on adult fecundity, and larval survival and growth for both species.
3. Shape of the functional response curve of mosquito density on damselfly predation rate.

4. Effects of temperature on damselfly attack rate and success.
5. Temporal and spatial dynamics of water pools and running water as a result of climate and weather factors.
6. Effects of water pool dynamics (desiccation or overflow) on mosquito and damselfly survival.

We will use a combination of field data and integrated laboratory experiments to measure these effects and calibrate relevant parameters. This information would then be used by Ahumada to develop a stochastic individual-based model to simulate the dynamics of mosquitoes and damselflies and predict responses under different annual climatic regimes and scenarios of global climate change.

PROCEDURES/METHODS:

Conduct field measurements of hydrologically-sensitive canopy characteristics in forests below, within, and above the current fog zone in Hawai'i

The cloud forest canopy hosts a dense epiphytic layer, and hence has a very high stem water storage capacity. To evaluate the hydrologic effect of the epiphytic layer, we will estimate stem water storage capacity at sites below, within, and above the cloud layer. In the field, representative samples of each type of stem water storage element, e.g. bare stems, mosses, bryophytes, and other vascular and non-vascular epiphytic plants, will be removed from an area outside the immediate area of each measurement site and taken to a nearby laboratory. We will fully saturate each sample by spraying a known volume of rainwater, while maintaining low evaporation conditions, and collecting the runoff. Storage capacity of bare stems (samples will consist of sections of recently fallen trees) will be taken as the difference between applied water and runoff, and expressed as volume per unit surface area of stem. Each epiphyte sample will be weighed at frequent intervals during drying. The storage capacity of each epiphyte sample will be taken as the difference between saturated mass and mass at a time just prior to visible desiccation of plant tissue, and expressed as volume of water per volume of plant material.

At sites below, within, and above the cloud layer, we will also conduct field measurements of stand Leaf Area Index (LAI) (using light interception methods), and soil hydrologic properties, including saturated hydraulic conductivity (using disk permeameters), bulk density, penetration resistance, particle size distribution, and organic carbon content.

Develop a model of cloud water interception based on surface wind velocity, liquid water content of surface air, and canopy characteristics

While field measurements of cloud water interception are essential to improve understanding, we cannot hope to capture the spatial variability of the process using only field observations. To answer important hydrological and ecological questions regarding tropical montane cloud forests, and to allow prediction of the effects of global change, we will develop a spatially distributed cloud water interception model (CWIM). We propose use the following relationship:

$$\mathrm{CWI} = 3600 \times \frac{\mathrm{LWC} \times z \times U}{d}$$

where CWI = cloud water interception [mm h^{-1}], LWC = liquid water content of air in the lowest model layer [kg m^{-3}]; z = vertical thickness of the exposed layer of intercepting vegetation [m]; U = wind velocity [m s^{-1}]; and d = distance of air flow through vegetation necessary to intercept an amount equivalent to the LWC [m]. The constant 86400 converts flux from per second to per hour value.

To obtain estimates of LWC and U, we will utilize output from the mesoscale meteorological model MM5. MM5 is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation (Haagenson et al. 1994; Oncley and Dudhia 1995). The Mauna Kea Weather Center is currently operating MM5 to provide operational forecasts for the Mauna Kea astronomical observatories. Output from the model includes spatially-distributed fields of liquid water content, wind speed and wind direction in the atmospheric layer in contact with the sloping ground surface on a 1-km grid. In this phase of the proposed project, we will initially focus our efforts on Hawaii Island, with the intention of expanding coverage to other Hawaiian Islands and eventually other Pacific Island groups. For each 1-km^2 grid in the model domain, hourly values of LWC and U are given by MM5.

The parameters z and d depend on canopy characteristics and the effectiveness with which cloud droplets are transported downward toward the intercepting vegetation. We propose to estimate these parameters through field measurement at the two sites described above. Based on these two sites, we will develop a parameterization scheme based on vegetation height, leaf area, and canopy roughness. Although this scheme will eventually require field measurements across a range of vegetation types, we will carry out a preliminary implementation of CWIM by estimating parameter values for the important vegetation classes found on Hawaii Island. Spatial distributions of these parameters will be assessed using GIS coverages of vegetation type.

The value of CWIM will be in it's ability to estimate the spatial distribution of cloud water input to the hydrological cycle. Running the model for long periods, using archived output from MM5, we will be able to develop the first estimates of the spatial patterns of cloud water interception for Hawaii. More importantly for the proposed project, CWIM will enable us to estimate how the spatial distribution of CWI will change in response to changes in the lifting condensation level (lower limit of the cloud zone), trade wind inversion (upper limit of the cloud zone), and shifts in vegetation resulting from future warming.

Paleoecology of Tropical Montane Cloud Forests

Histories of Chironomids and Megalagrion

In order to separate the response of ecosystem indicators from records of climate change, we will collect cores from two high-elevation lakes on Haleakala and use sediment composition, mineralogy, and geochemistry to develop records of climate change independent of the records of ecosystem response. We also hope to use deuterium, oxygen, and carbon isotopes in resistant algal compounds in both wetland and lake cores to reconstruct changes in temperature and precipitation. On Mauna Kea we will also develop a high-resolution tree ring climate history using Sophora chrysophylla in the relatively seasonal subalpine environment above the TMCF. Studies of chironomid remains near treeline in British Columbia and in the Alps show that the insects respond rapidly to climatic change, often more quickly than the vegetation (e.g. Heiri et al. 2003). With independent physical and chemical records of climatic change, we will be able to assess lags in response of vegetation and insect communities to a change in elevation of the trade wind inversion 6800-2200 years ago, as well as the temporal patterns of community change with climate change.

With the records of fire history we will develop in this phase of the project we will be able to assess the correlations climate, species composition, and rate of disturbance by fire over time, for both long- and short-lived species.

Chironomid head capsules are abundant in sediments of lakes and bogs, and they can be identified to the genus or sometimes species level. Methods of analysis and interpretation of chironomid assemblages are well developed (e.g. Marshall et al. 2002). Chironomid analysis has not yet been widely used in tropical ecosystems, but an Australian study has demonstrated the effectiveness of chironomids for paleoclimatic interpretation in a tropical volcanic maar lake (Dimitriadis and Cranston 2001). We will develop a local calibration data set, following the strategies tested by these earlier research projects. Surface sediment samples already collected will be analyzed for Chironomid remains, and additional samples will be added to the library, extending our sampling range to lower elevation and higher rainfall areas as well as to our new study areas on Mauna Kea and Mauna Loa.

Modeling Hydrologic Feedbacks and Trophic Interactions in Aquatic Communities

Some of the modeling work on mosquitoes is currently underway in a related NSF-funded Biocomplexity project started in 2000. This project integrates field and laboratory information into a modeling framework to understand the disease dynamics of avian malaria and pox in forested habitats along an elevation gradient in Puna on the east flank of Mauna Loa, Island of Hawaii. Our modeling team has already developed a temperature dependent and rainfall dependent model that makes specific predictions for mosquito dynamics along the gradient (Ahumada et al., in prep). The model is a stochastic difference equation projection that uses sub-diagonal parameter offsetting to simulate the effects of temperature on immature mosquito development (immature stages are modeled as physiological age classes or degree-days). The model also uses daily and accumulated precipitation to simulate the effects of drought on mosquito survival through a logistic function. This base model would serve as a template to develop a specific Megalagrion-mosquito model for this project. This effort requires extending the model to include riparian habitats, integrating Megalagrion dynamics and predation, developing a detailed calibration of climate effects on the demography of these species and understanding the role of climate in the system.

EXPECTED PRODUCTS:

Year 2

1. Workshop on case histories of the impacts of climate change in the Pacific (summer, 2004).
2. Publication submitted on hydrologic characteristics of the forest canopy and epiphytic layer in and near Hawaiian tropical montane cloud forest.
3. Report submitted on evapotranspiration and rainfall partitioning in Hawaiian tropical montane cloud forest.
4. Report submitted on A model of cloud water interception for tropical montane cloud forests.
5. Report submitted on interannual and long-term variability in the climate of mountain slopes in Hawai'i.
6. Report on distributions and new species records for chironomid flies in Hawaii, including a species-level taxonomic key.
7. Publication submitted on distribution of chironomid species relative to climate above, below, and within the cloud forest zone.
8. Publication submitted on the history of chironomid species at several sites on Haleakala.
9. Publication submitted on vegetation change on Haleakala over several recent time scales, from the recensus of various upland and wetland vegetation samples including the 5-year recensus of our vegetation transects.

10. Publication submitted on the use of aquatic species as indicators of hydrologic change in Hawaiian ecosystems.

Year 4

1. Publication submitted on effects of alien species invasion and climate variability on hydrological fluxes in Hawaiian forest.
2. Effects of climate variability and change on cloud water interception in Hawaiian tropical montane cloud forests.
3. Climate of the sub-canopy zone in Hawaiian tropical montane cloud forests.
4. Publication submitted on Holocene climate change from lake sediment analyses on Haleakala.
5. Publication submitted on the rates and nature of response of vegetation and insect communities to climate change and fire over the Holocene.
6. Publication submitted on modeling the impact of climate change on trophic interactions between Megalagrion damselflies and population cycles of alien mosquitoes.
7. Workshop on restoration and adaptive management of TMCFs

TECHNOLOGY/INFORMATION TRANSFER: Appendix 2 contains letters of support from DOI land managers interested in using results of this research to better manage montane ecosystems in the Pacific. Publications resulting from this work will be distributed to our partners in the Pacific, as well as other state and local agencies. We are also planning on organizing two workshops during the course of this project: The first will summarize case histories on the impacts of climate change in the Pacific and the second will be a workshop on restoration and adaptive management of TMCFs.

DATA MANAGEMENT: Our climatological data is currently available at: http://webdata.soc.hawaii.edu/climate/HaleNet/Index.htm We will continue to update this site and provide linkages with the National Biological Information Infrastructure Pacific Biological Information Node on Maui. We are also actively working with Gordon Dicus, the database manager for the National Park Service Pacific Islands Cluster in order to identify database needs to better integrate our study with the Vital Signs long-term ecological monitoring program that is currently under development in the Pacific.

PERSONNEL:
Lloyd Loope, PIERC Botanist, will serve as principal contact for the project and implement the management plan described below. Loope will also take the lead in summarizing case histories of climate change presented at the April 2004 workshop.
David Foote, PIERC Ecologist, will assist Loope in overseeing implementation of the management plan and will also be responsible permitting and satisfying other logistical needs of our federal partners in order to access field sites. Foote will also be responsible for installation and maintenance of the new weather station at NPSA and for conducting surveys of contemporary aquatic dipteran communities at paleoecological study sites with Cooperator O'Grady. He will also assist with Dr. LaPointe and Cooperator Jorge with developing models of trophic interactions between Megalagrion and chironomids.
Dennis LaPointe, PIERC Ecologist, will assist with surveys of mosquitoes and other aquatic diptera and model development with Ahumada and Foote.

MANAGEMENT PLAN: A workshop will be held during the first year of the project (2004) in order to summarize past climate change research in the Pacific Islands. Case histories regarding the impact of climate change on native ecosystems and biodiversity will be presented. Participation of project personnel and cooperators will be mandatory and time will be set aside for the first of five annual project leader meetings (APLMs). APLMs will be used as a means to assess progress and reallocate resources, if need be, in order to meet overall project goals and deliverables. These annual meetings will be held during summers and will facilitate evaluation of progress at a midpoint in the reporting cycle with annual progress reports due in January. A quarterly newsletter will be distributed to project personnel describing significant findings and progress toward milestones. As video conferencing capabilities are improved at PIERC, we will also explore this tool as a means to "meet" and interact as a group more frequently.

COOPERATORS/PARTNERS:
Thomas Giambelluca, University of Hawaii, will maintain the existing climate monitoring network at Haleakala and Hawaii Volcanoes National Park. He will also be responsible for developing spatial models of cloud water interception. He will also coordinate the collection of hydrological data at all the study sites.
Sara Hotchkiss, University of Wisconsin, Center for Climatic Research, University of Wisconsin, will coordinate the collection and analysis of vegetation data and paleoecological samples, and will facilitate interaction with general circulation modelers at the Center for Climatic Research.
Patrick O'Grady, University of Vermont, will be responsible for assisting with surveys of chironomid flies, preparing a taxonomic key to species, and reporting on species distributions.
Jorge Ahumada, University of Wisconsin, will be responsible for developing a model of trophic interactions between alien mosquito populations and Megalagrion along elevational gradients in Kau.
Daniel Gruner will serve as a postdoctoral researcher at the University of Wisconsin to develop and analyze paleoecological data on chironomids for climate history analysis.
Contact information for these partners are listed in individual qualification statements below.

FACILITIES/EQUIPMENT/STUDY AREA(S): The **Kilauea Field Station** of the **Pacific Islands Ecosystem Research Center** has a dedicated server and is part of DOINet. The **University of Hawaii at Manoa** currently serves climatological data **University of Wisconsin-Madison: The Center for Climatic Research**, a research department within the Institute for Environmental Studies, will contribute shared use of the following equipment and facilities to accomplish the goals of this project.
Laboratory: The Paleoecology Laboratory contains appropriate facilities for the safe chemical extraction of pollen, chironomids, and charcoal from sediments.

LEGAL AND POLICY-SENSITIVE ASPECTS: Upon funding, site visits will be undertaken at each national park and wildlife refuge where research is proposed. We will work with our federal partners in the National Park Service and the U. S. Fish & Wildlife Service to meet permitting and environmental compliance needs for each individual site. This will involve the development of site-specific protocols for access and conduct of field personnel. At NPSA, our work will also need to be coordinated with the local villages as part of lease arrangements for the property that makes up the park. Specimen collection permits will also be obtained from the Hawaii Department of Land and Natural Resources for forest reserves adjacent to federal lands. We have letters of support with contact information (see appendix 2) from all park and refuge managers for our proposed project.

WORK AND REPORTING SCHEDULE: Our budget is itemized to provide a schedule of work over five years and our list of expected products for reporting are listed above. Milestones will be met at year 2 and year 4 of the project. We will also meet the annual reporting requirements of the USGS-GCCP.

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Figure 1. (a) Annual temperature at Honolulu, Hilo, and Haleakala Ranger Station- trends based on linear regression of temperature vs. time;
(b) Five-year moving averages of 1944-2002 temperature anomalies for Haleakala and for the global mean (global anomalies obtained from Climatic Research Unit, East Anglia University, UK;
(c) January rainfall monthly averages for Honolulu, Hawaii with arrows indicating ENSO events; (d) Base flow for Halawa Valley stream, Molokai, computed from the method of Wahl and Wahl (1995).

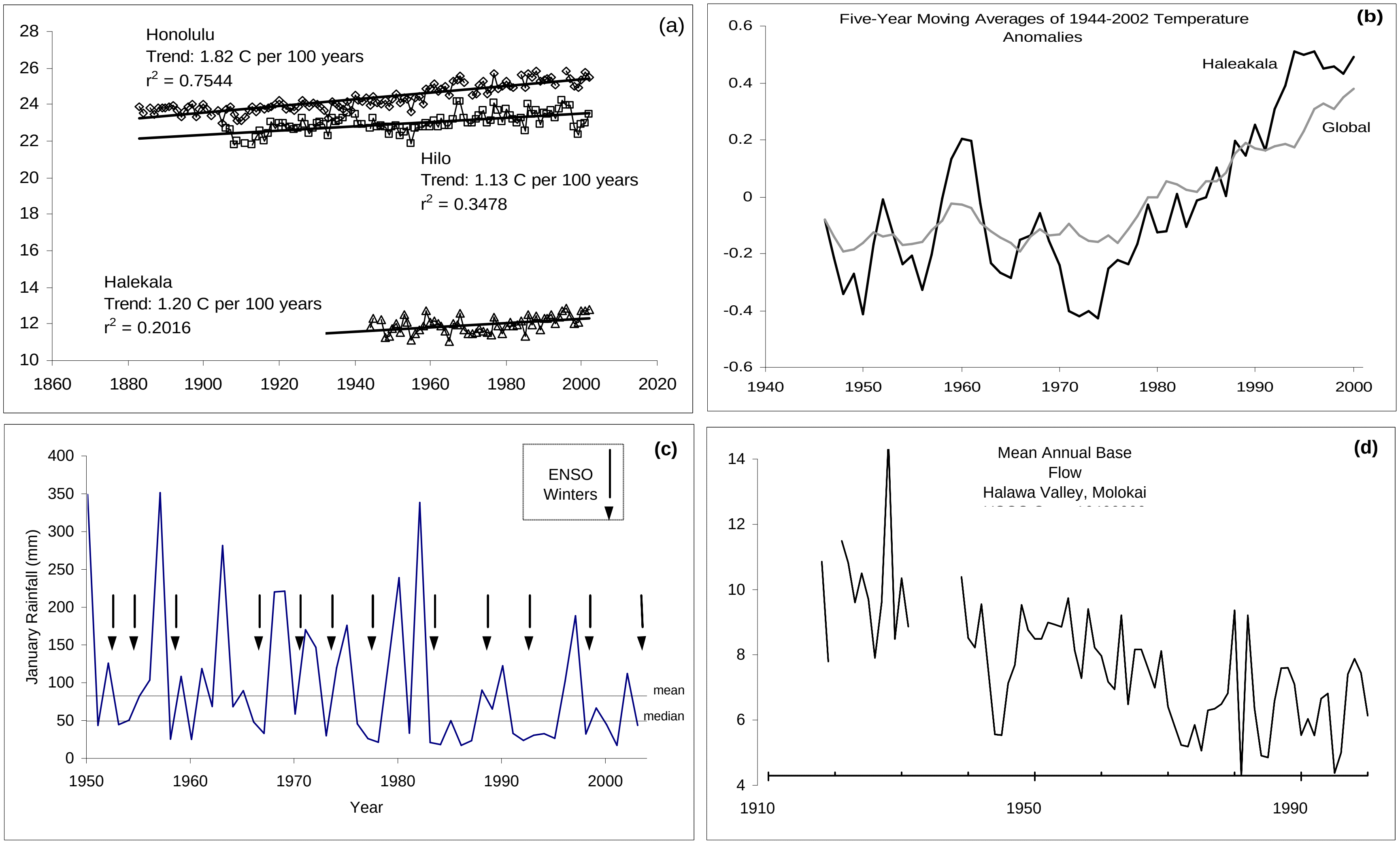
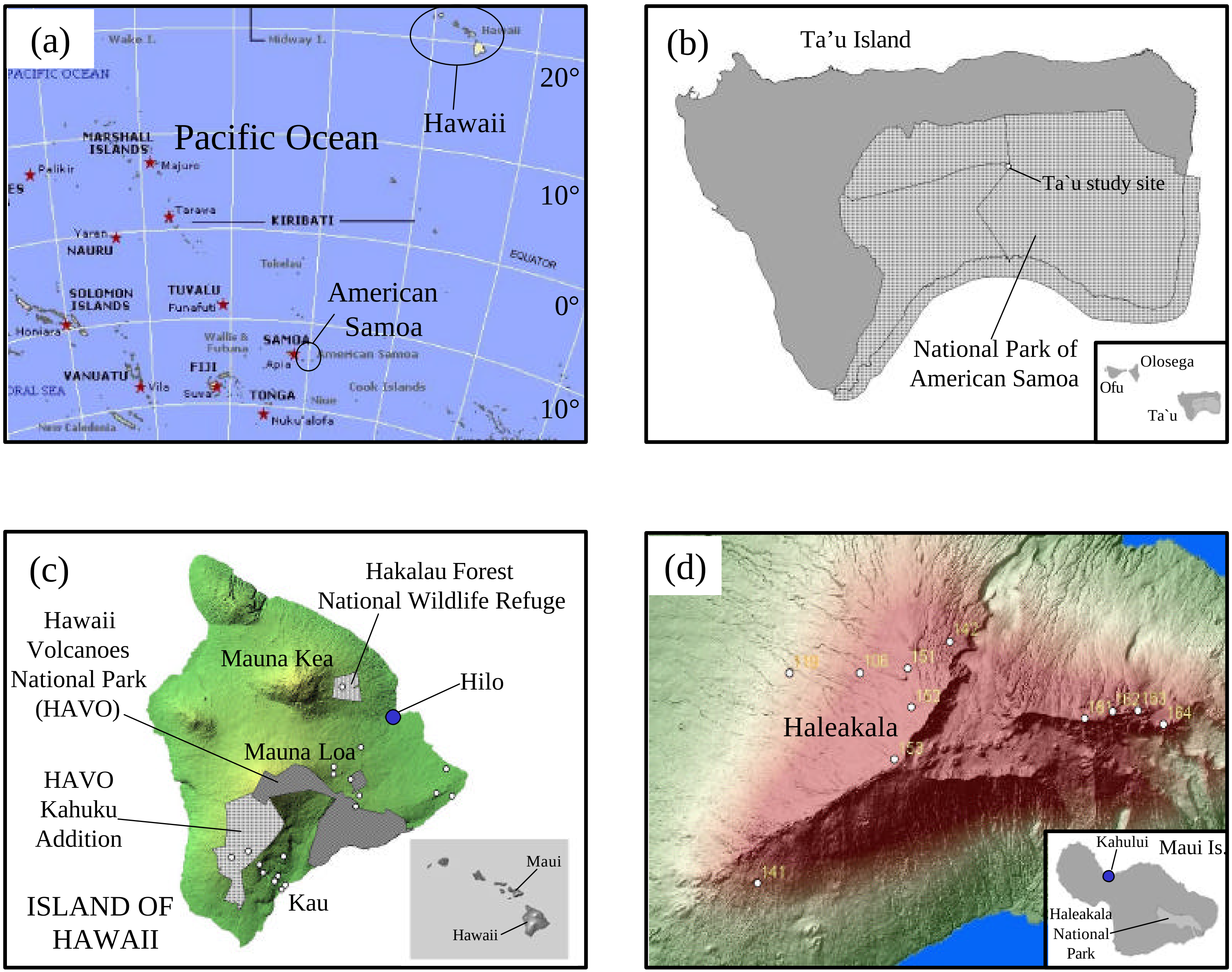


Figure 2: Proposed study sites



Project Title: Sensitivity of Pacific Island Tropical Montane Cloud Forests to Climate Change
Principal Investigator(s): Loope, Foote, LaPointe, Giambelluca, Hotchkiss, O'Grady, Ahumada

Cost Center: PIERC

BUDGET:	FY2004	FY2005	FY2006	FY2007	FY2008	TOTALS
1. Microclimatological and Hydrological Networks HALE & HALE						
SALARIES- Technician	18000	18450	18911	19384	19869	
PI Summer- Giambelluca	8600	8815	9035	9261	9493	
Graduate Student Assistant	0	0	17500	18025	18566	
FRINGE BENEFITS	6,650	6,816	11,362	11,668	11,982	
SUPPLIES	6,000	6,500	3,076	3,152	3,230	
TRAVEL- Hono-HALE	3200	3280	3362	3446	3532	
TRAVEL- Hono-HAVO	3200	3280	3362	3446	3532	
TOTAL	45,650	47,141	66,608	68,382	70,204	
INDIRECT COST	6,848	7,071	9,991	10,257	10,531	
SUBPROJECT TOTAL	52,498	54,212	76,599	78,639	80,735	342,682
2. Microclimatological and Hydrological Network NPSA						
SALARIES- Technician	18000	9000	9225	9456	9692	
FRINGE BENEFITS	4,500	2,250	2,306	2,364	2,423	
EQUIPMENT	26,294	0	0	0	0	
SUPPLIES	1,150	3,200	3,500	3,800	3,800	
TRAVEL- HAVO-NPSA	10,000	5,100	5,200	5,200	5,200	
OTHER	0	0	0	0	0	
TOTAL	59,944	19,550	20,231	20,820	21,115	
INDIRECT COST	4,875	2,453	2,510	2,553	2,597	
SUBPROJECT TOTAL	64,819	22,003	22,741	23,373	23,712	156,648
3. Paleoecology of Tropical Montane Cloud Forests						
SALARIES- Technician	29000	29725	30468	31230	32011	
Chironomid Postdoc Gruner			33000	33825		
Taxonomist- O'Grady	8,667	8884				
FRINGE BENEFITS	9,417	9,652	15,867	16,264	8,003	
SUPPLIES	1,550	360	1,740	350	360	
TRAVEL	3,200	3,200	3,200	3,200	1,600	
OTHER (shipping, etc.)	0	200	200	0	0	
TOTAL	51,834	52,021	84,475	84,869	41,974	
INDIRECT COST	7,775	7,803	12,671	12,730	6,296	
SUBPROJECT TOTAL	59,609	59,824	97,146	97,599	48,270	362,448
4. Hydrological feedbacks within aquatic communities						
SALARIES	23,000	23575	0	0	0	
Modeler Ahumada	48,100	49303				
FRINGE BENEFITS	5,761	5,894	0	0	0	
EQUIPMENT	0	0	0	0	0	
SUPPLIES	4,440	3,000	0	0	0	
TRAVEL	5,000	2,500	0	0	0	
OTHER	250	260	0	0	0	
TOTAL	86,551	84,532	0	0	0	
INDIRECT COST	5,064	4,795	0	0	0	
SUBPROJECT TOTAL	91,615	89,327	0	0	0	180,942
5. Management interactions and interagency partnerships						
Supplies	620	0	0	1,530	0	
Travel	4,900			4,900		
INDIRECT COST	828	0	0	965	0	
SUBPROJECT TOTAL	6,348	0	0	7,395	0	13,743
	FY2004	**FY2005**	**FY2006**	**FY2007**	**FY2008**	
TOTAL ANNUAL BUDGET	**274,888**	**225,366**	**196,486**	**207,005**	**152,717**	
PROJECT GRAND TOTAL (total amount requested from USGS Climate Change Program)						**1,056,463**

6. PIERC Matching funds (not part of project total)						
Indirect costs waiver	38,484	31,551	27,508	28,981	21,380	
Salary- Loope	4,500	4613	4728	4846	4967	
Salary- Foote	30,400	31160	31939	32737	33555	
Salary- LaPointe	3,800	3895	3992	0	0	
TOTAL	**77,184**	**71,219**	**68,167**	**66,564**	**59,902**	**343,037**
PROJECT GRAND TOTAL INCLUDING MATCHING						**1,399,499**
					Matching=	**24.51%**

Budget Justification

Investigators: USGS investigators will be funded by PIERC as a matching contribution to the project. FTE contributions include 5% GS-15 (Loope); 40% GS-12 (Foote); and 5% GS-12 (LaPointe). Giambelluca will be supported for 1 month of summer salary throughout the five years of the project and O'Grady will be supported for 1 month of summer salary during the first two years of the project.
Support Staff: All support staff and postdoctoral researchers (except Ahumada) will be hired through the Research Corporation at the University of Hawaii at a pay range 12-19, commensurate with experience. Ahumada will be supported through the University of Wisconsin.
Contractors: No contractors will be used during this project.
Travel: The largest portion of the travel budget will support travel from Hawaii to American Samoa to install, maintain and repair the climate station there. Costs for week-long visits are estimated at $2500 including airfare, based upon figures provide by NPS for their staff's travel. Most of the remaining funds support interisland travel for maintenance and repair of climatological stations. Additional funds are budgeted to support travel between Wisconsin and Hawaii field sites. Travel funds are also included in each of two planned workshops to support travel of invited "keynote" speakers (1 per workshop) and interisland travel for other attendees.
Equipment: One meteriological station is budgeted for. It is designed to match those currently in use at HAVONet and HALENet (see description in background section above).
Supplies: These include small dataloggers for NPSA, hardware for instrument masts and guys, replacement parts for corers and environmental chambers, Gortex raingear, a computer for modeling ($3000), etc.
Construction: No construction costs are needed.
Contracts & Agreements: Most of the funds requested will be included under a cooperative agreement with the Pacific Cooperative Studies Unit at the University of Hawaii. Funds to support Ahumada's work ($82,000) will be part of a cooperative agreement with the University of Wisconsin.
Publications: These costs are included under Other and some of the costs will be matched by the home institutions of the project scientists.
Other: Specimen and equipment will need to be shipped to Madison and Burlington and these costs are included.
Indirect Cost: The Pacific Cooperative Studies Unit at the University of Hawaii is in the process of reorganizing as a Cooperative Ecosystems Studies Unit. We are anticipating that the indirect costs with be set at 15% (David Duffy, pers. comm.) and have budgeted accordingly.

APPENDIX 1. QUALIFICATIONS OF PROJECT PERSONNEL:

1. Dr. Lloyd Loope, USGS Pacific Island Ecosystems Research Center
2. Dr. Thomas Giambelluca, Department of Geography, University of Hawaii
3. Dr. Sara Hotchkiss, Center for Climatic Research, University of Wisconsin
4. Dr. David Foote, USGS Pacific Island Ecosystems Research Center
5. Dr. Dennis LaPointe, USGS Pacific Island Ecosystems Research Center
6. Dr. Patrick O'Grady, Department of Biology, University of Vermont
7. Dr. Jorge A. Ahumada, USGS National Wildlife Health Center, Madison, Wisconsin
8. Mr. Daniel Gruner, Department of Zoology, University of Hawaii

LLOYD L. LOOPE
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EDUCATION:
B.S. 1965, Virginia Polytechnic Institute and State University, Major: Biology
Ph.D. 1970, Duke University (Botany); Specialty: Plant Ecology; Minor field: Forest Meteorology/Hydrology

PROFESSIONAL EXPERIENCE:
1969-present: Research Scientist (GS-11 to 14), USDI, NPS, NBS, and USGS-BRD. (1969-70: Office of the Chief Scientist; 1970-74: Grand Teton National Park, Wyoming; 1974-77: International Specialist; 1977-80: Everglades National Park, Florida; 1980-present: Haleakala National Park Field Station, Maui, Hawaii; GS-14 since 1988).

ADJUNCT APPOINTMENTS: Adjunct Faculty Member, Department of Botany and Center for Conservation Research and Training, University of Hawaii at Manoa, 1981-

SELECTED RELEVANT PUBLICATIONS:
Loope, L. L., and D. Duffy. 2001. Conclusion: Can we sustain Hawaiian ecosystems? (Abstract). Oral presentation at Symposium, Sustaining Island Ecosystems: Can it be achieved in Hawaii? Society for Conservation Biology, Hilo, Hawaii, July 2001.

Loope, L. L., F.G. Howarth, F. Kraus, and T.K. Pratt. 2001. Newly emergent and future threats of alien species to Pacific landbirds and ecosystems. Studies in Avian Biology 22:291-304.

Carter, L.M., E. Shea, M. Hamnett, C. Anderson, G. Dolcemascolo, C. Guard, M. Taylor, T. Barnston, Y. He, M. Larsen, **L. Loope**, L. Malone, and G. Meehl. In press (2001). Potential consequences of climate variability and change for the US-affiliated islands of the Pacific and Caribbean. Chapter 11 in Climate Change Impacts on the United States: the Potential Consequences of Climatic Variability and Change. U.S. Global Change Research Program and Cambridge University Press.

Loope, L.L., and T.W. Giambelluca. 1998. Vulnerability of island tropical montane cloud forests to climate change, with special reference to East Maui, Hawaii. *Climatic Change* 39:503-517.

Vitousek, P.M., C.M. D'Antonio, **L.L. Loope**, M. Rejmanek, and R. Westbrooks. 1997. Introduced species: a significant component of human-caused global change. *NZ Jour. Ecol.* 21:1-16.

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Loope, L.L., and A.C. Medeiros. 1994. Biotic interactions in Hawaiian high-elevation ecosystems, p. 337-354. *In* P.W. Rundel, A.P. Smith, and F.C. Meinzer (eds.), *Tropical Alpine Environments: Plant Form and Function.* Cambridge University Press. Cambridge, U.K.

Loope, L.L., O.H. Hamann, and C.P. Stone. 1988. Comparative conservation biology of oceanic archipelagoes: Hawaii and the Galapagos. *BioScience* 34(4): 272-282.

Thomas W. Giambelluca
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Education:

Ph.D. Univ. of Hawai'i at Manoa, Geog., Specialization: Climatology/Water Res., 1983

M.A. Univ. of Miami, Florida , Geog., Specialization: Climatology, 1977

Relevant Publications:

Giambelluca, T.W. & Niemand, C. In preparation. A case study on the relationships among fog, rainfall, & throughfall on East Maui, Hawai'i.

Giambelluca, T.W., Ziegler, A.D., Nullet, M.A., Dao, T.M., & Tran, L.T. 2003. Transpiration in a small tropical forest patch. *Agric. & Forest Meteorol.* 117: 1-22.

Giambelluca, T.W. 2002. Hydrology of altered tropical forest. *Hydr. Proc.* 16:1665-1669.

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Giambelluca, T.W., Fox, J., Yarnasarn, S., Onibutr, P., & Nullet, M.A. 1999. Dry-season radiation balance of land covers replacing forest in northern Thailand. *Agricultural & Forest Meteorology* 95:53-65.

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Giambelluca, T.W., Ridgley, M.A., & Nullet, M.A. 1996. Water balance, climate change, & land-use planning in the Pearl Harbor Basin, Hawai`i. *International Journal of Water Resources Development* 12:515-530.

Giambelluca, T.W., Tran, L.T., Ziegler, A.L., Menard, T.P., & Nullet, M.A. 1996. Soil-vegetation-atmosphere processes: Simulation & field measurement for deforested sites in northern Thailand. *J. Geophys. Res. (Atmospheres)* 101:25,867-25,885.

Giambelluca, T.W. 1996. Tropical land cover change: Characterizing the post-forest land surface. In T.W. Giambelluca & A. Henderson-Sellers (eds.), *Climate Change: Developing Southern Hemisphere Perspectives*. Wiley & Sons, UK, pp. 293-318.

Giambelluca, T.W., & Nullet, D. 1992. Evaporation at high elevations in Hawaii. *J. Hydrol.* 136:219-235.

Nullet, D., & Giambelluca, T.W. 1992. Radiation climatology through the trade-wind inversion. *Physical Geography* 13(1):66-80.

Giambelluca, T.W., & Nullet, D. 1991. Influence of the trade-wind inversion on the climate of a leeward mountain slope in Hawaii. *Climate Research* 1(3):207-216.

Giambelluca, T.W. 1983. Water balance of the Pearl Harbor--Honolulu basin, Hawai`i, 1946--1975. Technical Report 151, Water Res. Research Center, Univ. of Hawaii, Hono. xi+151pp.

Giambelluca, T.W., Nullet, M.A., Ridgley, M.A., Eyre, P., Moncur, J., & Price, S. 1991. Drought in Hawai`i. Report R88, Div.Water & Land Dev., Haw. Dept. Land & Nat. Res., Hono., xix+232pp.

Giambelluca, T.W. 1986. Land use effects on the water balance of a tropical island. *National Geographic Research* 2(2):125-151.

Giambelluca, T.W., Nullet, M.A., & Schroeder, T.A. 1986. Hawaii Rainfall Atlas, Report R76, Hawaii Div. of Water & Land Devel., Dept. of Land & Natural Resources, Honolulu. vi + 267pp.

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Professional Preparation:

Oberlin College, Biology & Ethnomusicology, B.A. 1987;
University of Minnesota, Ecology & Quaternary Paleoecology, Ph.D. 1998;
Stanford University, Ecosystem ecology & species invasion, postdoctoral work, 1998-2000.

Appointments:

Bryson Professor of Climate, People, & Environment, Center for Climatic Research, 2003;
Director of Paleoecology, Center for Climatic Research, 2002-present;
Assistant Professor, Department of Botany, University of Wisconsin, 2001-present;
Postdoctoral Research Associate, Stanford University, 1998-2000;
Assistant Scientist, Department of Geology & Geophysics, University of Wisconsin, 1998-2000.

Honors:

Reid A. Bryson Distinguished Professorship of Climate, People, & Environment, 2003-;Buell Award for excellence in ecology, Ecological Society of America, 1996; Deevey Award for presentation in paleoecology, Paleoecology Section of the Ecological Society of America, 1996; Gaudreau Award for excellence in Quaternary studies, American Quaternary Association, 1996.

Publications related to this proposal:

Werner, K., & S. Hotchkiss. Montane bog vegetation response to feral ungulate disturbance & exclosure. To be submitted to Wetlands October 2003.
Hotchkiss, S., & C. Douglas. Modern pollen assemblages & vegetation from the Island of Hawai‘i. Submitted to Journal of Biogeography July 2003.
Hotchkiss, S.C. In press. Quaternary history of the U.S. tropics. *In* A.Gillespie, S. Porter, & B. Atwater, eds. The Quaternary Period in the United States. Elsevier, New York.
Hotchkiss, S., P.M. Vitousek, O.A. Chadwick, & J. Price. 2000. Site history & the interpretation of soil & ecosystem development. Ecosystems 3:522-533.
Hotchkiss, S.C. & J.O. Juvik. 1999. A Late-Quaternary pollen record from Ka‘au Crater, O‘ahu, Hawai‘i. Quaternary Research 52: 115-128.
Hotchkiss, S.C. 1998. Quaternary vegetation & climate of Hawai‘i. Ph.D. dissertation, University of Minnesota, Twin Cities.

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EDUCATION: B.S. 1984, University of California, Berkeley, Major: Zoology
M.S. 1989, University of California, Davis, Major: Ecology
Ph.D. 1997, University of California, Davis, Major: Ecology

PROFESSIONAL EXPERIENCE:

1997-present: Research Ecologist (GS-11 to 12) USDI USGS-BRD Pacific Island Ecosystems Research Center (PIERC)
1996-97- Student Trainee (Ecology), PIERC
1994-96- Acting Station Leader, Hawaii Nat'l. Park Field Station, Coop. Parks Studies Unit (CPSU)
1991-94- Research Associate, CPSU, University of Hawaii

AFFILIATE FACULTY APPOINTMENTS: Ecology, Evolutionary & Conservation Biology, University of Hawaii at Manoa, 1998-present.

SELECTED RELEVANT PUBLICATIONS:

Foote, D. & D. Polhemus. In prep. Last known population of *Megalagrion nesiotes* persists through 4-year drought cycle on Maui. For submission to Bishop Museum Occasional Papers

Orr, K.E. & **D. Foote**. 2003. Sensitivity of Hawaiian ecosystems to climate change: Seasonal responses of Megalagrion damselflies to temperature gradients & moisture stress. (Abstract) Poster presentation at the Hawaii Conservation Conference, July. Honolulu, Hawaii

Tunison, T. & **D. Foote**. 2003. Models for interactions between research & resources management at Hawaii Volcanoes National Park. (Abstract) Invited joint oral presentation at the Hawaii Conservation Conference, July. Honolulu, Hawaii

Cooper, I.R. & **D. Foote.** 2003. Damselfly response to simulated drought: population size, territory size & naiad size. (Abstract) Invited oral presentation. Pacific Entomology Conference, February. Honolulu, Hawaii

Jordan, S., **D. Foote**, R. Englund & C. Simon. 2002. Phylogeography, population genetics, & conservation of the Hawaiian damselflies Megalagrion xanthomelas & M. pacificum. Submitted to Evolution- in revision.

Foote, D. 2000. Rediscovery of *Drosophila heteroneura* on the Island of Hawai'i. Bishop Museum Occasional Papers 64:27-28.

Jordan, S., **D. Foote**, & C. Simon. 2000. Phylogeography, population genetics, & conservation of the Hawaiian damselflies *Megalagrion xanthomelas* & *M. pacificum* (Abstract). Hawaii Conservation Biology Conference, Honolulu, Hawaii.

Foote, D., 1995 Patterns of diversity in island soil fauna: Detecting functional redundancy, pages 57-71 in *Islands: Biological diversity & ecosystem function*, edited by P. Vitousek, H. Adersen, & L. Loope. Springer-Verlag, Berlin.

Foote, D. & H. L. Carson. 1995. *Drosophila* as monitors of change in Hawaiian ecosystems. *Our Living Resources*. National Biological Survey, Washington, D.C.

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EDUCATION

B.S.Entomology	1974-1978, University of Massachusetts, Amherst, MA.
M.S. Entomology	1978-1982, University of Massachusetts, Amherst, MA. Thesis: The effect of host age on mosquito attraction, feeding, & fecundity.
Ph.D. Entomology	1992-2000, University of Hawaii, Honolulu, HI. Dissertation: Avian malaria in Hawaii: The distribution, ecology & vector potential of forest-dwelling mosquitoes.

RELEVANT EXPERIENCE

Ecologist, 1997-present, USGS-BRD-PIERC, Hawaii Field Station, Hawaii National Park, HI. Field & laboratory research in vector biology & control of avian malaria. Supervisor: Dr. William Steiner

Research Assistant, 1992-1997, Department of Entomology, University of Hawaii at Manoa, Honolulu, HI. Field & laboratory research concerning the entomological aspects of avian malaria. Supervisor: Dr. M. Lee Goff

Vector Control Consultant, 1986-1991, Amherst, MA. Monitored pest mosquito populations & evaluated the use of B.t.i. for control in various habitats. Evaluated new mosquito repellants.

Laboratory Technician, 1983-1984, Department of Entomology, University of Massachusetts, Amherst, MA. Mosquito endocrine studies using microdissection & organ culture techniques. Supervisor: Dr. John Stoffolano.

RELEVANT PUBLICATIONS

Ahumada, Jorge A., M. Samuel, A. P. Dobson, **D.A. LaPointe** & C.T. Atkinson. 2003. A simple individual-based model for the transmission of avian malaria in Hawaii (Abstract). Ecological Society of America Annual Meeting, August. Savannah, GA.

D.A. LaPointe. 2000. Avian Malaria in Hawaii: The Distribution, Ecology & Vector Potential of Forest-Dwelling Mosquitoes. PhD Dissertation. University of Hawaii at Manoa, Honolulu, HI. 156 pp.

LaPointe, D.A. 2002. First report of a water mite in the Family Pionidae (Acari: Parasitengona: Hygrobatoidea) in the Hawaiian Islands. Bishop Museum Occasional Papers.69: 41-42.

Benning, T.L., **D.A. LaPointe**, C.T. Atkinson & P.M. Vitousek. 2002 Interactions of climate change with biological invasions & land use in the Hawaiian Islands: Modeling the fate of endemic birds using a geographic information system. Proceedings of the National Academy of Sciences. 99(22): 14246-14249.

Fonseca, D.M., **D.A. LaPointe** & R.C. Fleischer. 2000. Bottlenecks & multiple introductions: population genetics of the vector of avian malaria in Hawaii. Molecular Ecology. 9:1803-1814.

Patrick Michael O'Grady II
University of Vermont Patrick.OGrady@uvm.edu
Department of Biology http://research.amnh.org/molecular/ogrady.html
Burlington, VT 05405

Education

1993 – 1998	University of Arizona, Tucson, Arizona, Ph.D., Genetics (minor: Ecology & Evolutionary Biology)
1989 – 1993	Clarkson University, Potsdam, New York, B.S., Biology

Recent Research Positions

2003 – present	Assistant Professor, Department of Biology, University of Vermont
2003 – present	Research Associate, American Museum of Natural History
2000 – 2003	Curatorial Associate, American Museum of Natural History
1999 – present	Visiting Scientist, University of Hawai'i, Center for Conservation Research & Training

Relevant Workshops

Drosophila Species Identification & Culture. I-III; National *Drosophila* Species Stock Center, Tucson, AZ; (co-organizer/instructor. 2001-2003)

Systematics Toolkit Workshop; New York Botanical Garden, New York, NY; November 2002 (instructor)

Relevant Publications

O'Grady, P. M., Kam, M. W. Y, Val, F. C., Pereirra, W. 2003. Revision of the *Drosophila mimica* subgroup, with descriptions of ten new species. *Annals of the Entomological Society of America*: 96(1): 12-38.

O'Grady, P. M., Bonacum, J., DeSalle, R., & Val, F. C. 2003. The placement of the *Engiscaptomyza*, *Grimshawomyia*, & *Titanochaeta*, three clades of endemic Hawaiian Drosophilidae. *Zootaxa* 159: 1-16.

O'Grady, P. M. 2002. Notes on the nomenclature of the endemic Hawaiian Drosophilidae. *Bishop Museum Occasional Papers* 65: 36-40.

O'Grady, P. M., Beardsley, J. W., & Perreira, W. D. 2002. New island & new state records for introduced Drosophilidae (Diptera) in Hawai'i. *Bishop Museum Occasional Papers* 65: 34-35.

O'Grady, P. M., Vela, D. & Rafael, V. 2002. *Zygothrica desallei*: A new species of Drosophilidae (Diptera) from Ecuador. *Annals of the Entomological Society of America* 31(3): 314-315.

Etges, W. J., Armella, M. A., O'Grady, P. M., & Heed, W. B. 2001. Two new species of *Drosophila* (Diptera; Drosophilidae) in the *repleta* group from Mexico. *Annals of the Entomological Society of America* 94(1): 16-20.

Hardy, D. E., Kaneshiro, K. Y., Val, F. C., & O'Grady, P. M. 2001. Review of the *haleakalae* species group of Hawaiian *Drosophila* (Diptera: Drosophilidae). Bishop Museum Bulletin in Entomology 9: 1-88. Bishop Museum Press.

O'Grady, P. M., Val, F. C., Hardy, D. E., & Kaneshiro, K. Y. 2001. The *rustica* species group of Hawaiian *Drosophila* (Diptera: Drosophilidae). Pan-Pacific Entomologist 77(4):254-260.

CURRICULUM VITAE: **Jorge A. Ahumada**
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EDUCATION

Ph.D. in Ecology & Evolutionary Biology. 1996. Department of Ecology & Evolutionary Biology, Princeton, NJ 08544-1003. Thesis title: The effects of environmental variation on the reproduction & ecology of two neotropical wrens.

M.A. in Ecology & Evolutionary Biology, 1992. Department of Ecology & Evolutionary Biology, Princeton, NJ 08544-1003.

B.Sc. in Biology 1988. Departamento de Ciencias Biológicas, Universidad de Los Andes, Bogotá.

PROFESSIONAL EXPERIENCE

Postdoctoral Research Associate (since 01/02). USGS/National Wildlife Health Center

- Tasks: Modeling disease dynamics in hawaiian bird communities. Biocomplexity project.
- Annual Salary: $36,000 US/year

Postdoctoral Research Associate (01/00-12/01). Department of Botany, University of Georgia (Steve Hubbell).

- Tasks: Statistical modeling of survival & growth in the BCI plot.
- Annual Salary: $28,000 US/year.

Assistant Profesor (1995-1999). Department of Biology, Universidad Javeriana,.

- Tasks: Teaching at graduate & undergraduate level, research.
- Annual Salary: approx. $22,000 US/year.

RELEVANT PUBLICATIONS

1. Ahumada, J.A., LaPointe, D. & Samuel, D. Modeling the population dynamics of the southern house mosquito (*Cullex quinquefasciatus*) along an elevational gradient in Hawaii. In preparation
2. Ahumada, J.A., Borda-de-Agua, L., Svennings , J., Rathbun, S. & Hubbell, S.P. Statistical tools for the analysis of spatially dependent binary data: a primer for ecologists. In preparation.
3. Hubbell, S.P., Ahumada, J.A., Condit, R. & Foster, R. 2001. Local neighborhood effects & long-term survival of individual trees in a neotropical Forest. *Ecological Research* 16: 859-75.
4. Ahumada, J.A. 2001. Comparison of the reproductive biology of two neotropical wrens in an unpredictable environment in northeastern Colombia. *Auk* 118 (1): 191-210.
5. Stevenson, P., Quiñones, M.J. & Jorge A. Ahumada. 2000. Influence of Fruit Availability on Ecological Overlap among Four Neotropical Primates at Tinigua National Park, Colombia. *Biotropica*, 32(3):533-544.
6. Ahumada, J.A. 2000. Uso de modelos demográficos en el manejo de especies amenazadas. *Perez Arbelaezia*, 5(11):77-84.

DANIEL S. GRUNER
Short Curriculum Vitae

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Education

1994- Ph.D. candidate in Zoology, EECB Specialization, University of Hawai`i at Manoa

Dissertation (advisor: Andrew D. Taylor): Local & regional influences on the arthropod diversity & community structure of *Metrosideros polymorpha* (Myrtaceae) in the Hawaiian Islands.

1996 Ecology Fundamentals Course, Organization for Tropical Studies, Costa Rica.

1993 A.B. magna cum laude, Phi Beta Kappa, Honors in Biology, Hamilton College
Thesis (advisor: Ernest H. Williams): Field mark-recapture & laboratory studies of population biology of the nymphalid butterfly *Phyciodes tharos*.

Publications

Gruner, D.S. *In review.* Interacting influences of birds & resources on arthropod trophic structure on Hawai`i Island. *Ecology.*

Gruner, D.S. *In review.* Biotic resistance conferred by an insectivorous bird assemblage on Hawai`i Island. *Ecology Letters.*

Gruner, D.S. & A.D. Taylor. *In prep.* Resource & predator constraints on species composition & diversity in a Hawaiian arthropod community.

Gruner, D.S. *In prep.* Guild structure & species diversity of a canopy arthropod community across a geological chronosequence in the Hawaiian Islands.

Gruner, D.S. & D.A. Polhemus. 2003. Arthropod communities across a long chronosequence in the Hawaiian Islands. Pages 135-145 in Basset, Y., V. Novotny, S.E. Miller, & R. Kitching, eds. *Arthropods of Tropical Forests: Spatio-Temporal Dynamics & Resource Use in the Canopy.* Cambridge, UK: Cambridge University Press.

Gruner, D.S. 2003. Regressions of length & width to predict arthropod biomass in the Hawaiian Islands. Pacific Science 57(3):325-336.

Gruner D.S., R.A. Heu, & M. Chun. 2003. Two ant species (Hymenoptera: Formicidae) new to the Hawaiian Islands. Bishop Museum Occasional Papers 74:35-40.

Gruner, D.S. & D. Foote. 2001. Management Strategies for Western Yellowjackets in Hawaii. Report to the Packard Foundation (via the Secretariat for Conservation Biology).

Wetterer, J.K., D.S. Gruner, & J E Lopez. 1998. Foraging & nesting ecology of the leaf-cutting ant, Acromyrmex octospinosus, in a Costa Rican tropical dry forest. Florida Entomologist 81(1):61-67.

APPENDIX 2. LETTERS OF SUPPORT FROM PACIFIC ISLAND DOI LAND MANAGERS

1. Don Reeser, Superintendent, Haleakala National Park
2. Richard Wass, Refuge Manager, Hakalau Forest National Wildlife Refuge
3. Tim Tunison, Chief of Resources Management, Hawaii Volcanoes National Park
4. Doug Neighbor, Superintendent, National Park of American Samoa

United States Department of the Interior

National Park Service

Haleakalä National Park

P. O. Box 369
Makawao, Maui, Hawai'i 96768

IN REPLY REFER TO:

N-22

September 20, 2003

To whom it may concern:

Haleakalä National Park fully supports the USGS proposal for continued climate change research. We are proud that NPS supported establishment & maintenance of HaleNet in the early 1990s & that USGS has enhanced the effort during the past five years. Our resource management program has consistently assisted with the challenging logistics of maintaining the remote windward portion of the network as well as with the paleoecology work in our remote montane bogs. HaleNet is undoubtedly the best climate network in the state & in the Pacific region for understanding effects of changes in atmospheric parameters & ocean currents on high-elevation environments. Given that one of the Park's most important mandates is to protect Hawaiian plants, animals, & ecosystems unaltered for future generations, understanding the nature & effects of climate change is crucial for us. We believe that it is important to build on what is becoming a very strong long-term data set. As the long-term high-elevation rainfall record becomes stronger, would like to see the connection made between rainfall data & USGS streamflow records which date back for nearly a century.

The work also seems important to the entire community on Maui & statewide to allow better quantification of water budgets for assessing ground water recharge. On West Maui, water tables have been dropping in the past two decades in response to water withdrawal for human use &/or drought. Understanding long-term trends & effects of climate change will contribute to better planning & management.

Sincerely,

Donald W. Reeser
Superintendent
808-572-4401

FWS Letter for Hakalau Forest National Wildlife Refuge situated on Mauna Kea Volcano on the Island of Hawaii (note this letter makes mention of a proposal section title that was dropped in the present proposal to meet space requirements).

U. S. Department of the Interior
U. S. Fish & Wildlife Service
Hakalau Forest National Wildlife Refuge
32 Kinoole St., Suite 101
Hilo, HI 96720
September 19, 2003

David Foote, Ph.D.
U. S. Geological Survey
Pacific Island Ecosystems Research Center
P. O. Box 44
Hawaii National Park, HI 96718

Dear David,

Hakalau Forest National Wildlife Refuge is located on the east slope of Mauna Kea & was established to protect endemic forest birds & plants, & their habitat. The refuge is committed to reforestation & forest restoration to accomplish these goals. The refuge is excited to see that a proposal for research at the refuge entitled; “Mauna Kea high-resolution climate history, vegetation history, & restoration Vegetation history from charcoal, seeds, phytoliths, pollen; High resolution climate history from wood” is being submitted.

We support this research because information gained will be of use in two current projects aimed at restoring vegetation to improve endangered bird & plant habitat in a disturbed & virtually treeless pasture belt encircling Mauna Kea between *Metrosideros/Acacia* koa forests below & treeline *Sophora* forests above. The innovative use of phytoliths, seeds in soil profiles, pollen in small hollows, seeps & springs, tree ring widths & isotopes of deuterium, carbon, & hydrogen in wood of *Sophora* & *Acacia koa* will give us insights as to past plant communities destroyed by 200 years of human disturbance. Isotope profiles & tree ring widths will allow us to develop high-resolution records of precipitation & temperature & give us climate histories that extend beyond the available observational records, greatly increasing our ability to predict the response of high elevation ecosystems to climatic phenomena such as El Ni? o.

When funding is confirmed & the research shown to meet refuge compatibility requirements, we will work with you to issue a Special Use Permit (SUP) which gives access to the area & permits the research. The SUP will cover access routes & will specify protocols as described in your proposal. Special Conditions attached to the SUP will minimize the risk of adverse impacts on wildlife & habitat. We would like to be involved in the project where ever possible & can provide logistical & manpower support where needed.

Sincerely
Richard C. Wass
Refuge Manager 808-933-6915

Climate Change Program
U.S. Geological Survey
Biological Resources Discipline
Office of the Chief Scientist (MS301) Attn: Stan Coloff
12201 Sunrise Valley Drive
Reston, Virginia 20192

18 September 2003

To Whom It May Concern:

I am writing in support of the proposal by David Foote, Dennis LaPointe & Lloyd Loope to continue research directed at long-term climate change in Hawaii Volcanoes National Park. Foote & Loope have been instrumental in establishing meteorological stations at HAVO & Haleakala National Park (HALE). Since the first HAVO station was established by Foote & his colleagues in 1999, the climate data has been used by graduate students & other researchers to increase our understanding of moisture budgets & the impacts of drought in the park. One significant finding was the observation that more than half of the moisture budget at Thurston Forest is accounted for by input from cloudwater rather than direct precipitation. This input has not previously been quantified, despite weather stations operating in the park since 1916. There is also high potential for this research to help guide long-term restoration efforts underway in the park. For example, the current proposal calls for the establishment of elevational transects to sample charcoal, seeds & pollen in order to evaluate past patterns of vegetation. This will be very helpful as the park embarks on an ambitious program to restore large sections of the newly acquired Kahuku Ranch. Furthermore, a better understanding of interannual variability in moisture & temperature trends will help establish realistic targets for restoration. This proposal represents an important blend of basic & applied climate research that will be of considerable value to the National Park Service in Hawaii.

Tim Tunison
Chief of Resources Management
Hawaii Volcanoes National Park
808-985-6085
Tim_Tunison@nps.gov

United States Department of the Interior
NATIONAL PARK SERVICE
National Park of American Samoa
Pago Pago, American Samoa 96799

IN REPLY REFER TO:

To Whom It May Concern:

I am writing in support of the proposed climate change study by Dr. David Foote & colleagues. Dr. Foote's proposed research will greatly benefit the National Park of American Samoa by establishing the first weather station in the park & monitoring weather trends in the cloud forest on Ta'u. This is a critical resource that is of great interest to the National Park Service, as it represents the only mixed species, paleotropical rainforest in the service.

Detecting any change or trend in the climate of Ta'u is critical to our efforts to preserve the park, as it will help managers to determine if future changes in the structure of the cloud forest/montane environment & marine environment are occurring due to global weather patterns or other reasons. Our only data to date consists of two stations on Tutuila, & the results are conflicting. This study would provide us with another source of data & help us determine if trends observed in the region are real or perceived, & allow us to examine a relatively pristine environment. The project has my full endorsement pending a site visit by USGS & park staff to determine study feasibility, the development of protocols, & environmental compliance by the National Park Service. Thank you for your time.

Sincerely,

Doug Neighbor
Superintendent